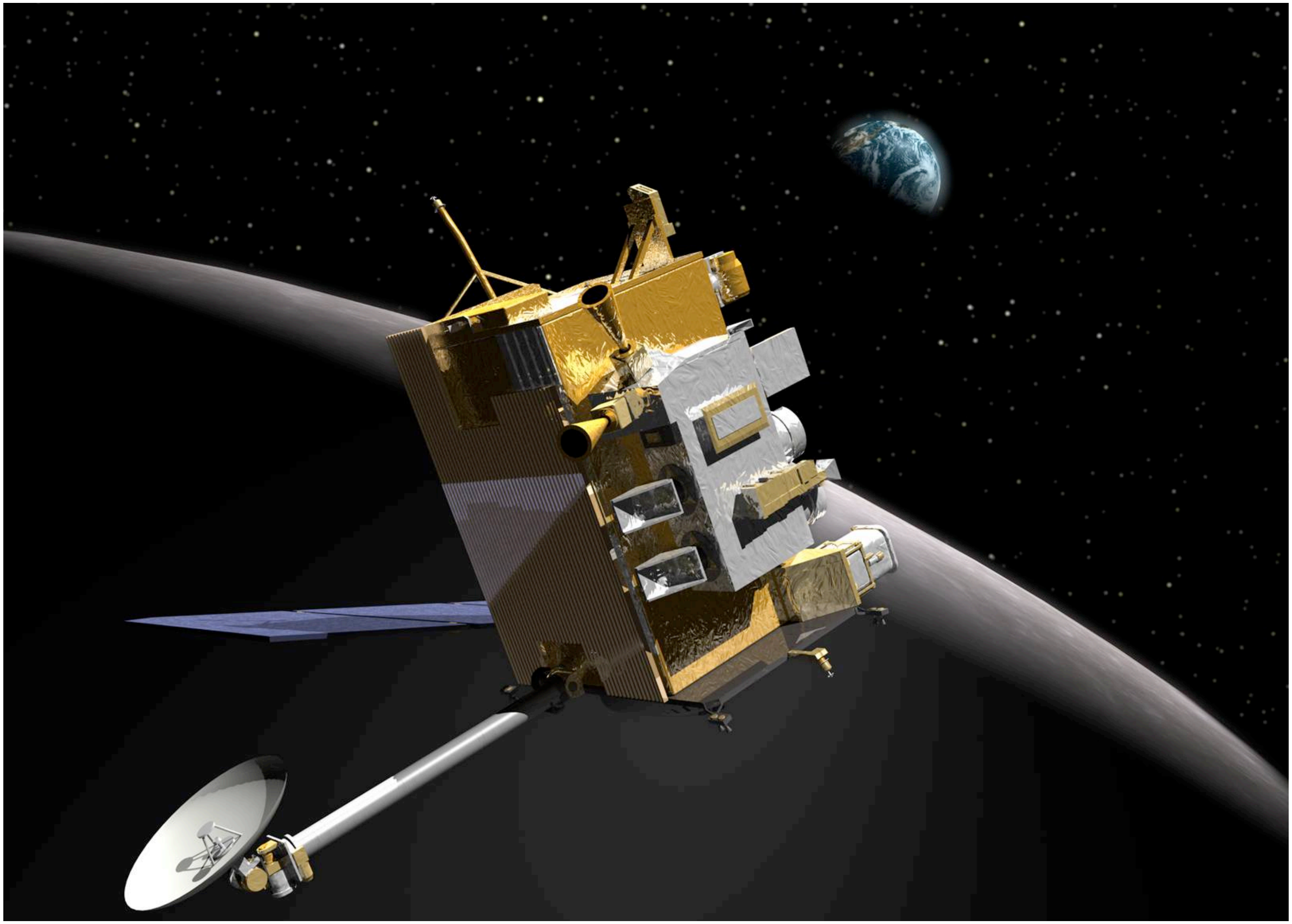
Lunar Reconnaissance Orbiter: Instrument Suite and Objectives

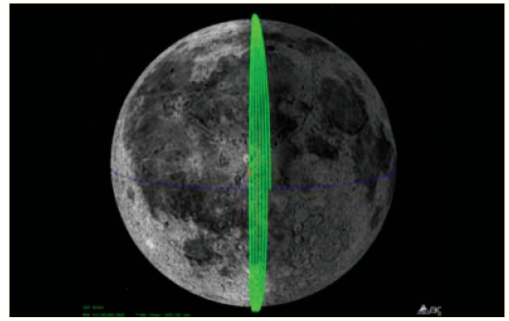


LRO Objectives

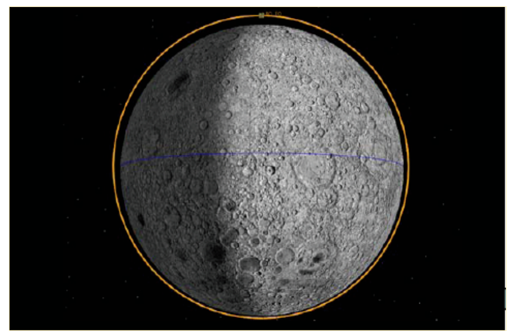
- Safe Landing Sites
  - High resolution imagery
  - Global geodetic grid
    - Topography
    - Rock abundances
- Locate potential resources
  - Water at the lunar poles?
  - Continuous source of solar energy
  - Mineralogy
- Space Environment
  - Energetic particles
  - Neutrons
- New Technology
  - Advanced Radar

LRO Mission Overview

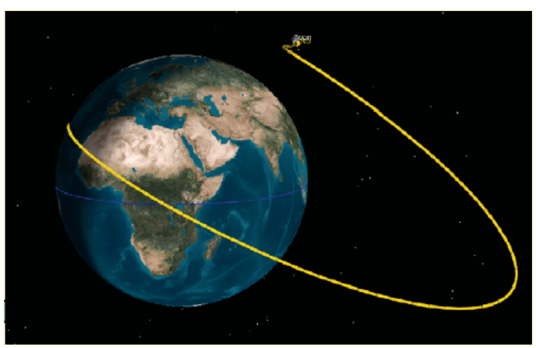
- Launch on an Atlas V into a direct insertion trajectory to the moon. Co-manifested with LCROSS lunar impactor mission.
- On-board propulsion system used to capture at the moon, insert into and maintain 50 km mean altitude circular polar orbit.
- 1 year exploration mission followed by handover to NASA Science Mission Directorate.
- Orbiter is 3-axis stabilized, nadir pointed, operates continuously during the primary mission.
- Data products delivered to Planetary Data Systems (PDS) within 6 months of completion of primary mission.

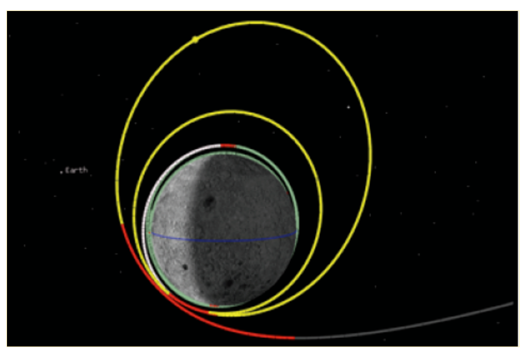


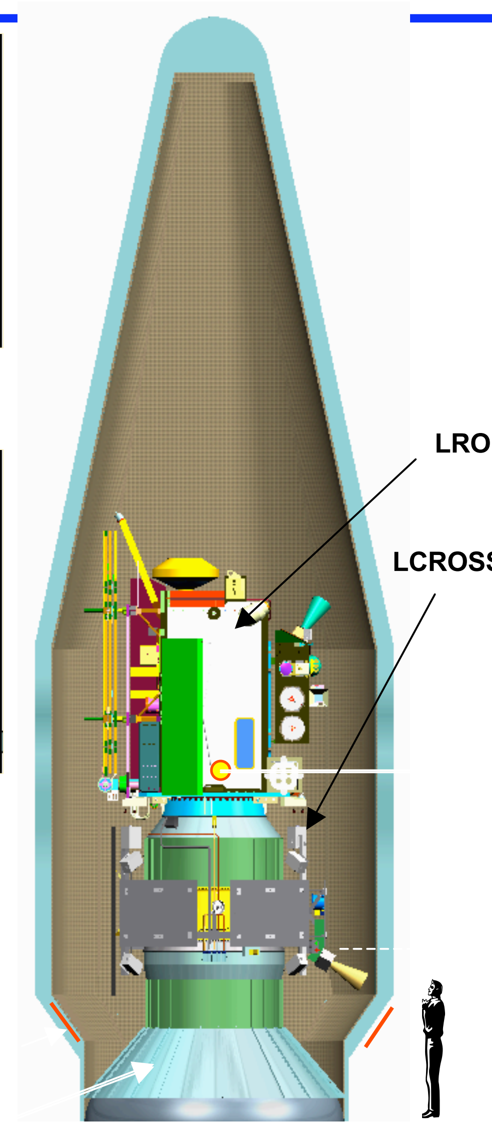
Polar Mapping Phase, 50 km Altitude Circular Orbit, At least 1 Year



Commissioning Phase, 30 x 216 km Altitude Quasi-Frozen Orbit, Up to 60 Days



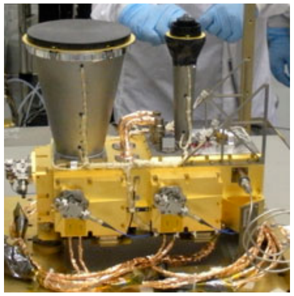




Instrument Overview

LOLA: Lunar Orbiter Laser Altimeter

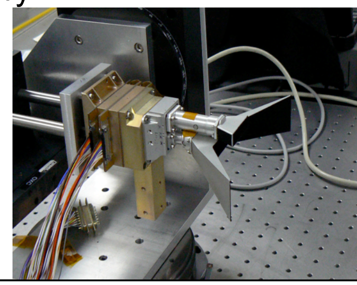
- Topography
- Slopes
- Roughness



Full Orbit
Autonomous

LROC/WAC: Wide-Angle Camera

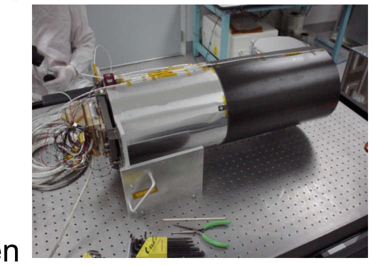
- Global Imagery
- Lighting
- Resources



Day Side
Autonomous

LROC/NACs: Narrow-Angle Cameras

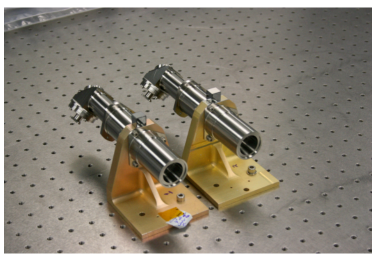
- Targeted Imagery
- Hazards
- Topography



Day Side
Timeline Driven

LR: Laser Ranging

- Topography
- Gravity



GSFC LOS
Autonomous

DLRE: Diviner Lunar Radiometer Exp.

- Temperature
- Lighting
- Hazards
- Resources

Full Orbit
Autonomous

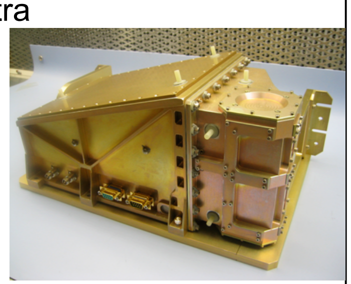
Mini-RF: Synthetic Aperture Radar

- Tech Demonstration
- Resources
- Topography

Polar Regions
Timeline Driven

CRaTER: Cosmic Ray Telescope…

- Radiation Spectra
- Tissue Effects



Full Orbit
Autonomous

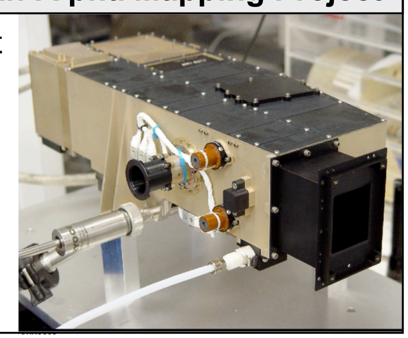
LEND: Lunar Explr. Neutron Detector

- Neutron Albedo
- Hydrogen Maps

Full Orbit
Autonomous

LAMP: Lyman-Alpha Mapping Project

- Water-Frost
- PSR Maps

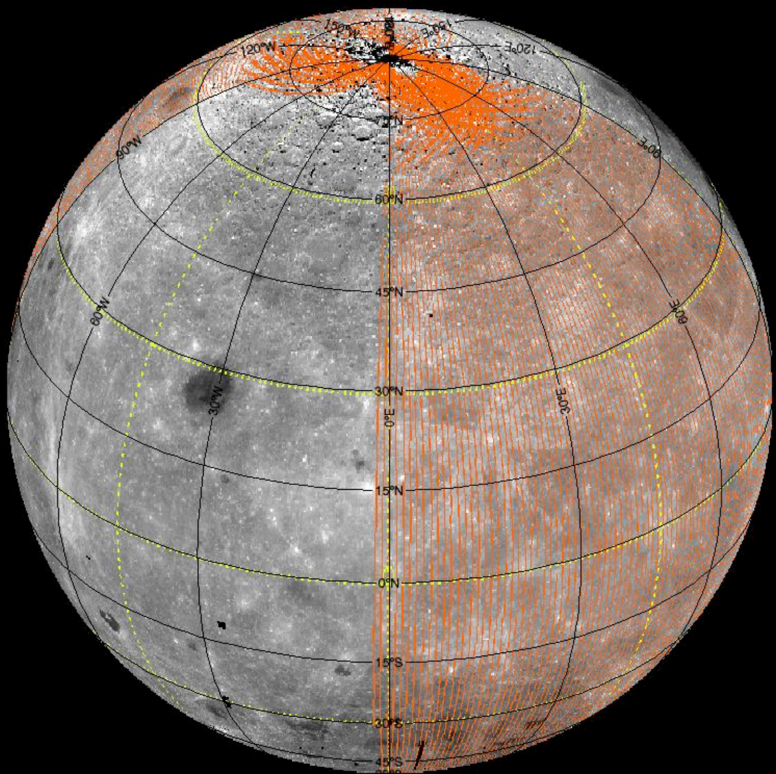


Night Side
Autonomous

After 1 year of operation to accomplish Exploration objectives, LRO will be operated by NASA's Science Mission Directorate

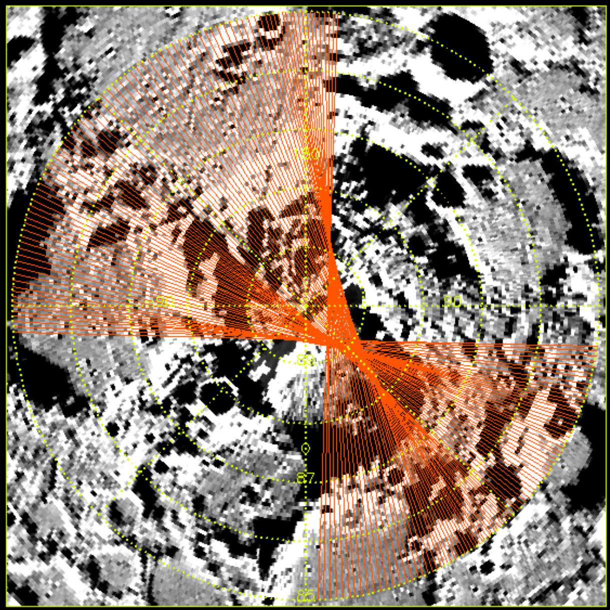
- SMD mission might be operated in a different orbit (e.g. more complete coverage over the moon's lower latitudes, or in a more stable orbit for prolonged operations)
- SMD will provide funding for the LRO Principal Investigators, as well as for a Participating Scientist Program (24 LRO Participating Scientists recently selected)
- All LRO data products will be delivered to the Planetary Data System within six months for use by the scientific community
- LRO instrument suite has strong planetary science heritage
- Measurement capabilities align with lunar science goals that were identified by the NRC Decadal Survey

LRO Emphasizes the Lunar Poles

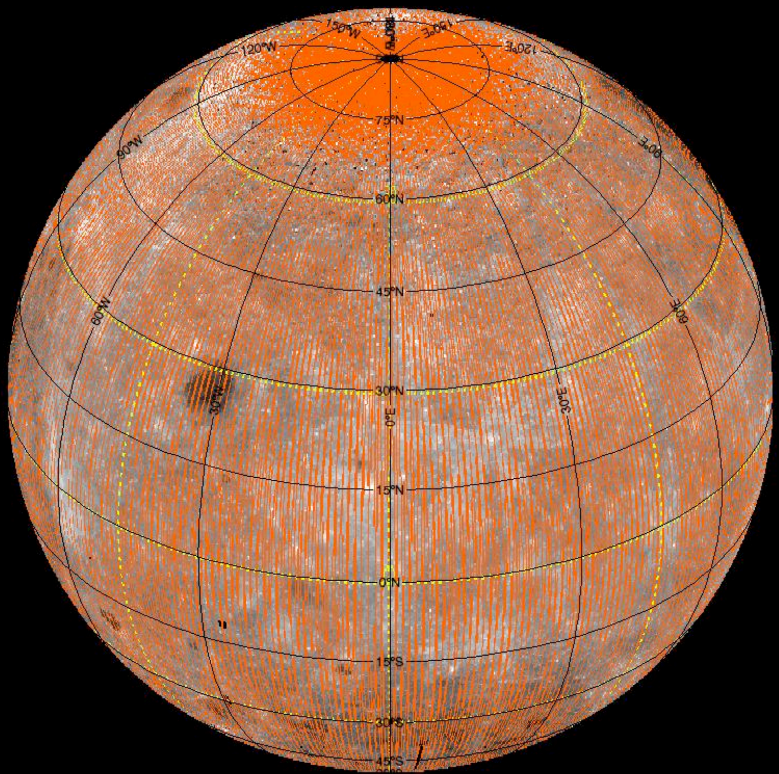


7 day orbital ground track prediction

North Pole.

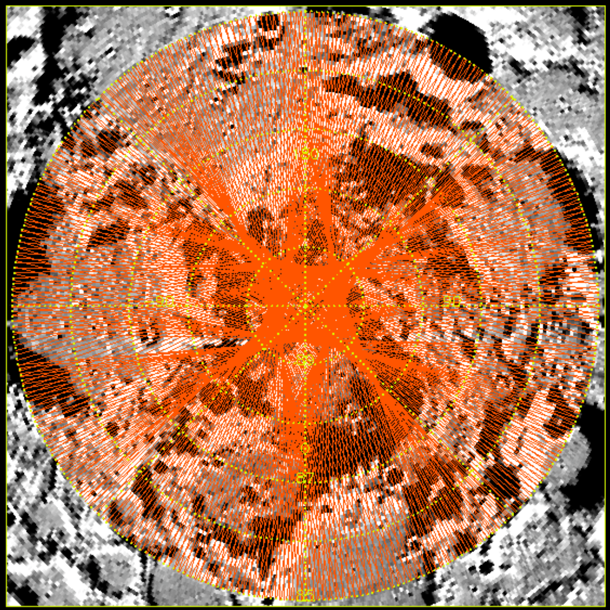


LRO Emphasizes the Lunar Poles



27 day orbital ground track prediction

North Pole.

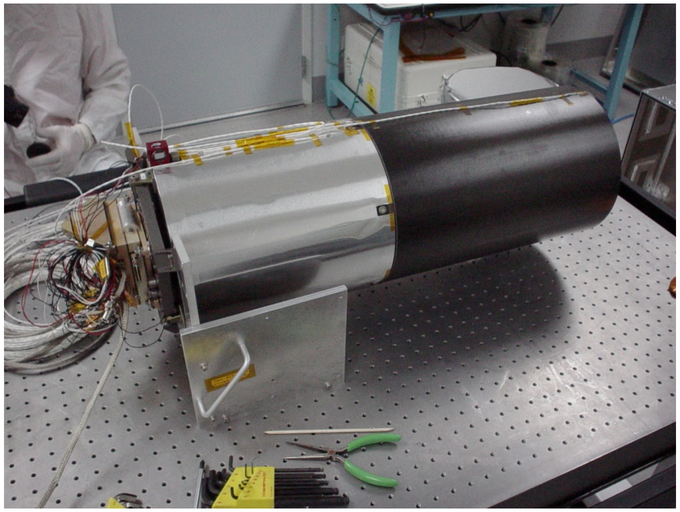


Lunar Reconnaissance Orbiter Camera (LROC)

Mark Robinson PI, ASU

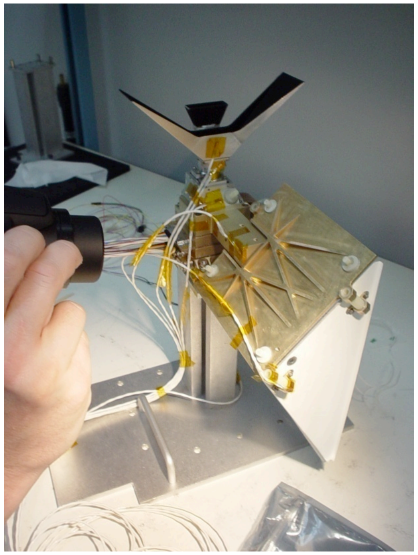
Wide and Narrow Angle Cameras (WAC, NAC)

- WAC Design Parameters
  - Optics (2 lenses) f/5.1 vis., f/8.7 UV
    - Effective FL 6 mm
    - FOV 90º
    - MTF (Nyquist) > 0.5
  - Electronics 4 circuit boards
    - Detector Kodak KAI-1001
    - Pixel format 1024 x 1024
    - Noise 30 e-
- NAC Design Parameters
  - Optics f/3.59 Cassegrain (Ritchey-Chretien)
    - Effective FL 700 mm
    - FOV 2.86º (5.67º for both)
    - MTF (Nyquist) > 0.15
  - Electronics
    - Detector Kodak KLI-5001G
    - Pixel format 1 x 5,000
    - Noise 100 e-
    - A/D Converter AD9842A
    - FPGA Actel RT54SX32-S



NAC

WAC Filters
#1 - 315
#2 - 360 nm
#3 - 415 nm
#4 - 560 nm
#5 - 600 nm
#6 - 640 nm
#7 - 680 nm



WAC

LROC Science/Measurement Summary

- Landing site identification and certification, with unambiguous identification of meter-scale hazards.
- Meter-scale mapping of polar regions with continuous illumination.
- Unambiguous mapping of permanent shadows and sunlit regions including illumination movies of the poles.
- Overlapping observations to enable derivation of meter-scale topography.
- Global multispectral imaging to map ilmenite and other minerals.
- Global morphology base map.

LROC NAC camera will provide 25 x greater resolution than currently available

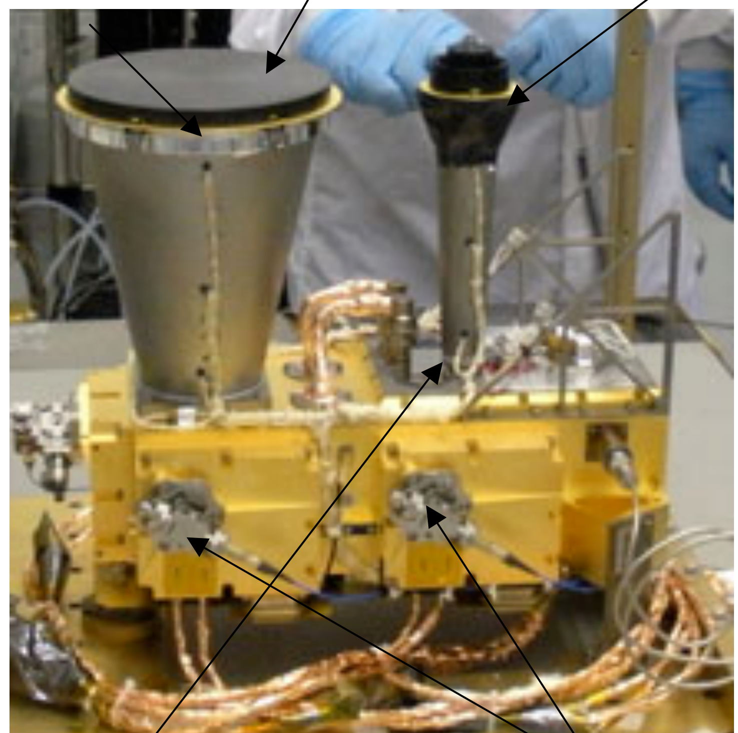
50 cm pixel dimension from 50 km

Images geodetically tied to LOLA

Lunar Orbiter Laser Altimeter (LOLA)

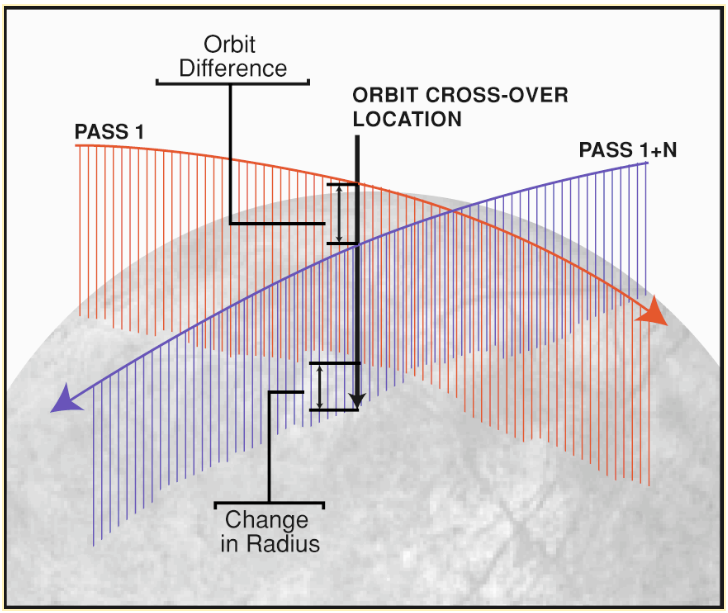
Dave Smith PI, GSFC Maria Zuber co-PI

- **LOLA measures:**
  - <u>RANGE</u> to the lunar surface (pulse time-of-flight)
    ±10cm (flat surface)
  - <u>REFLECTANCE</u> of the lunar surface (Rx Energy/Tx Energy)
    ± 5%
  - <u>SURFACE ROUGHNES</u> (spreading of laser pulse)
    ± 30 cm
- Laser pulse rate 28 Hz, 5 spots => ~ 4 billion measurements in 1 year.

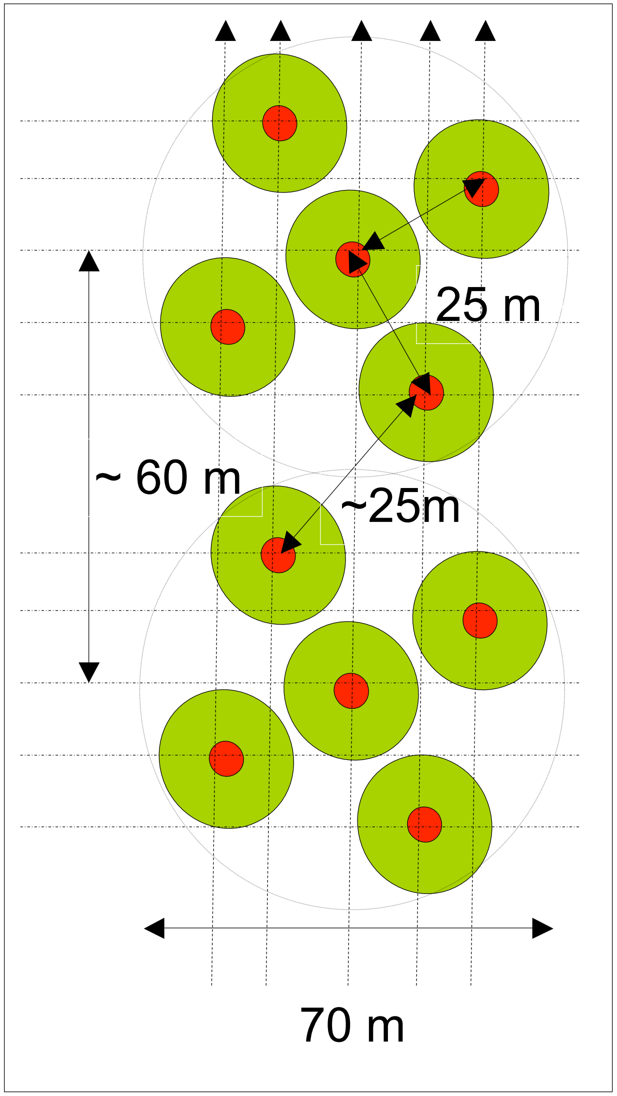


LOLA will Derive an Accurate Global Lunar Reference System

- **LOLA will obtain an accuracy base of ~50 meters horizontal (point-to-point) and 0.5 to 1 meter radial**
  - Current accuracy ~4 km
- **LOLA is a geodetic tool to derive a precise positioning of observed features with a framework (grid) for all LRO Measurements**
  - Measure distance from LRO to the surface globally
  - Laser ranging from ground station to LRO provides precise orbit determination
  - Five laser spots along and across track
  - Measure distribution of elevation within laser footprint
  - Enhanced surface reflectance (possible water ice on surface)

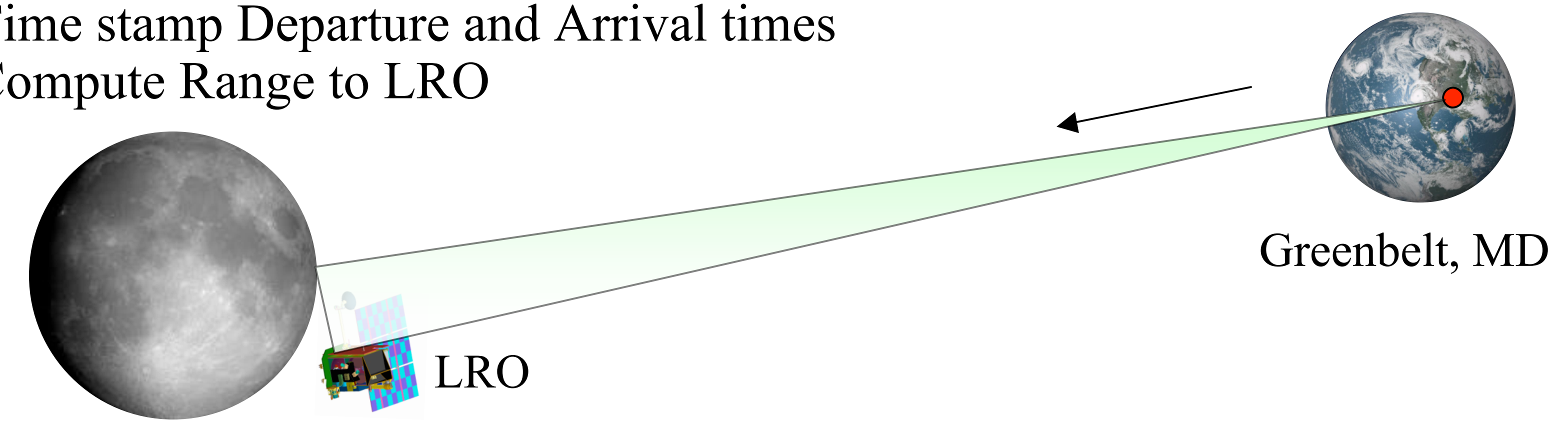


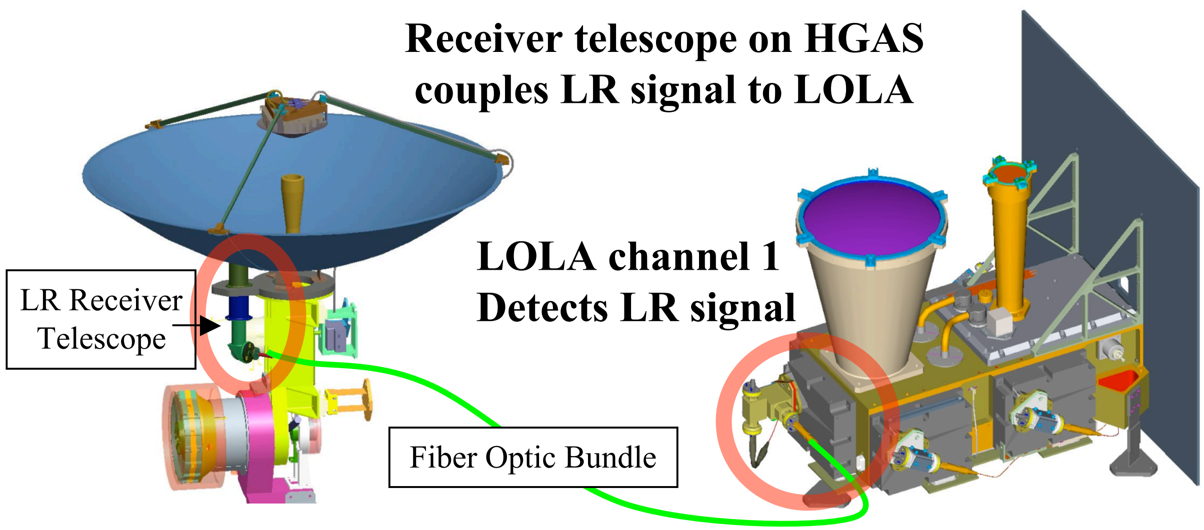
Crossovers occur about every 1 km in longitude and 3 deg in latitude at equator



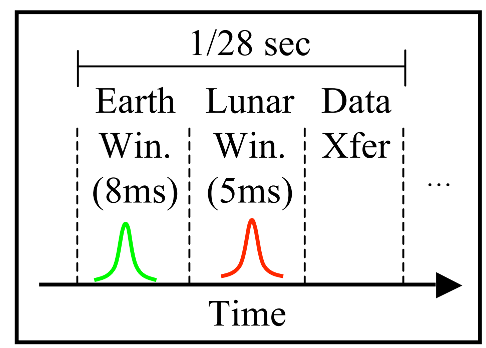
Laser Ranging Overview

- Transmit 532 nm laser pulses at 28 Hz to LRO
- Time stamp Departure and Arrival times
- Compute Range to LRO





LR Timeshares LOLA Detector With Lunar surface returns

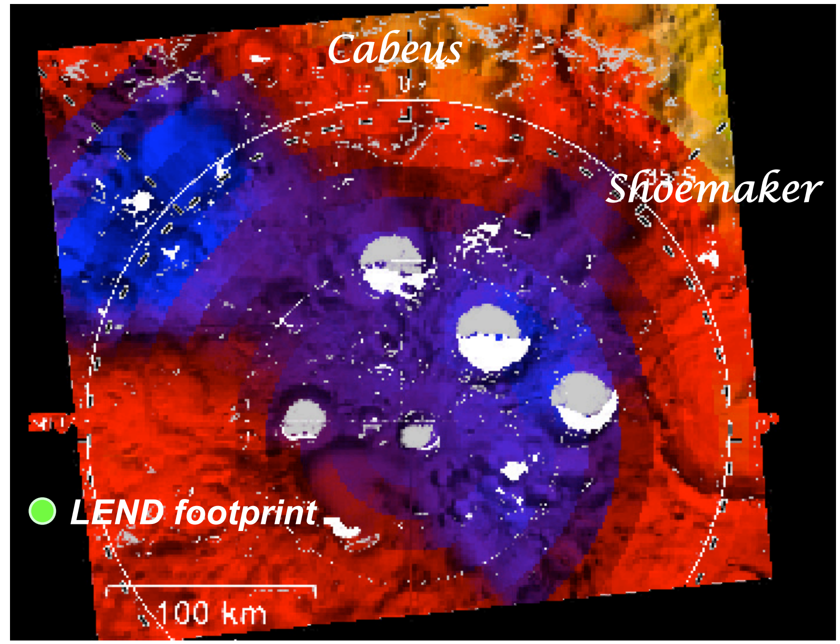


Lunar Exploration Neutron Detector (LEND)

Igor Mitrofanov PI, IKI

- LEND is designed to measure lunar thermal, epithermal and energetic neutrons.
- LEND improves spatial resolution for epithermal neutrons from 140km to 10km to locate areas of high hydrogen concentration
- LEND footprint smaller than the Permanently Shadowed Regions of interest
- Improves sensitivity of measurements in cold spots
- Enables site selection

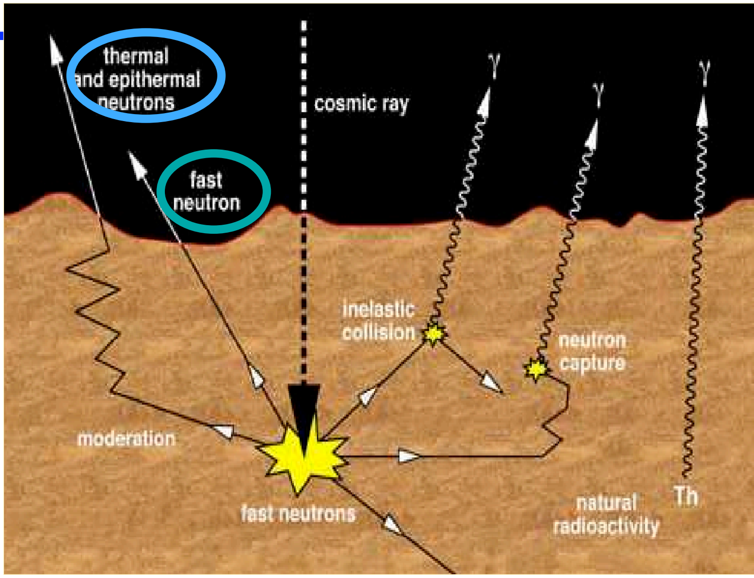
South Pole

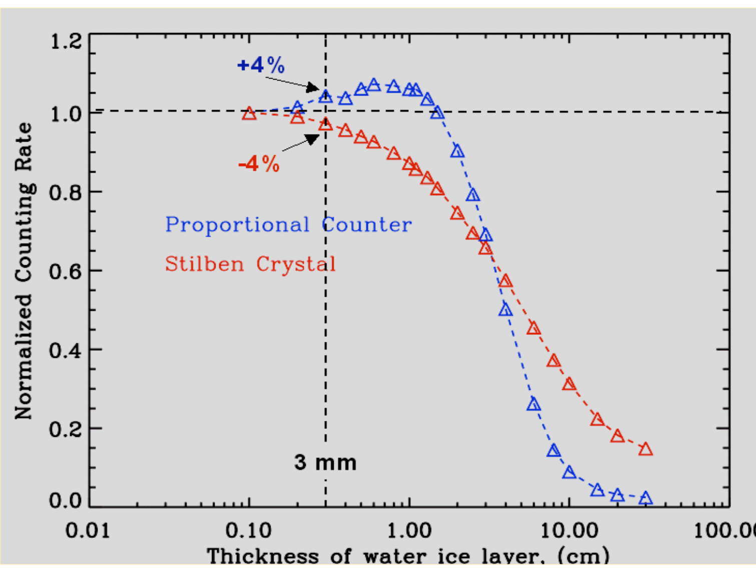


Shackleton

White areas represent permanently shadowed regions as determined from ground based radar and overlaid on Lunar Prospector hydrogen concentrations

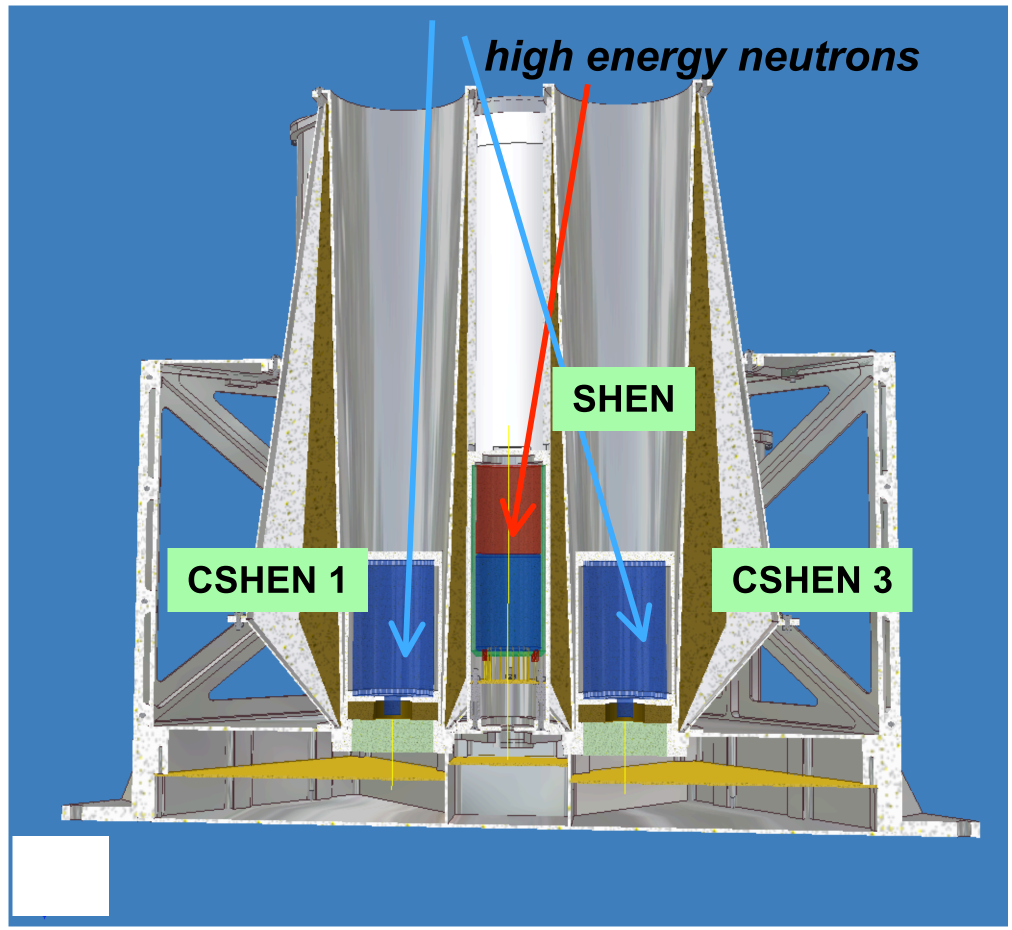
LEND Science Overview and Theory of Operations





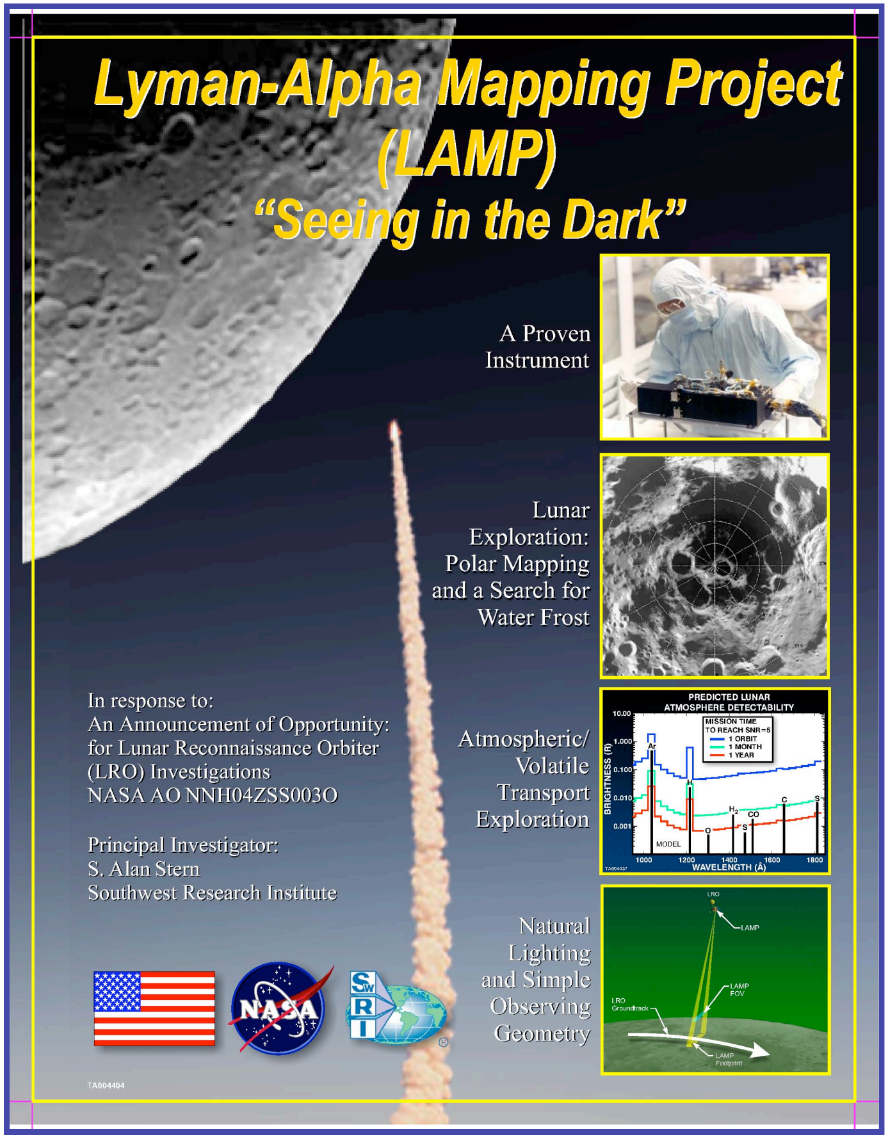
LEND collimated sensors CSETN1-4 and SHEN detect epithermal neutrons and high energy neutrons with high angular resolution to test water ice deposit on the surface

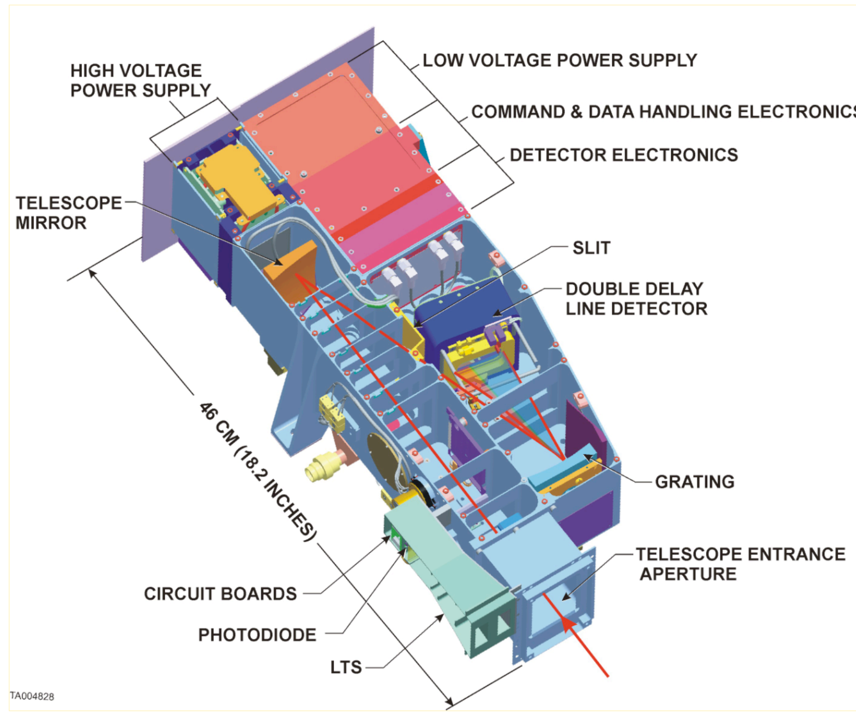
epithermal neutrons



Lyman-Alpha Mapping Project (LAMP)

Alan Stern PI, SwRI, Randy Gladstone (SwRI), Acting PI





LAMP (with LTS):

5.3 kg, 4.6 W

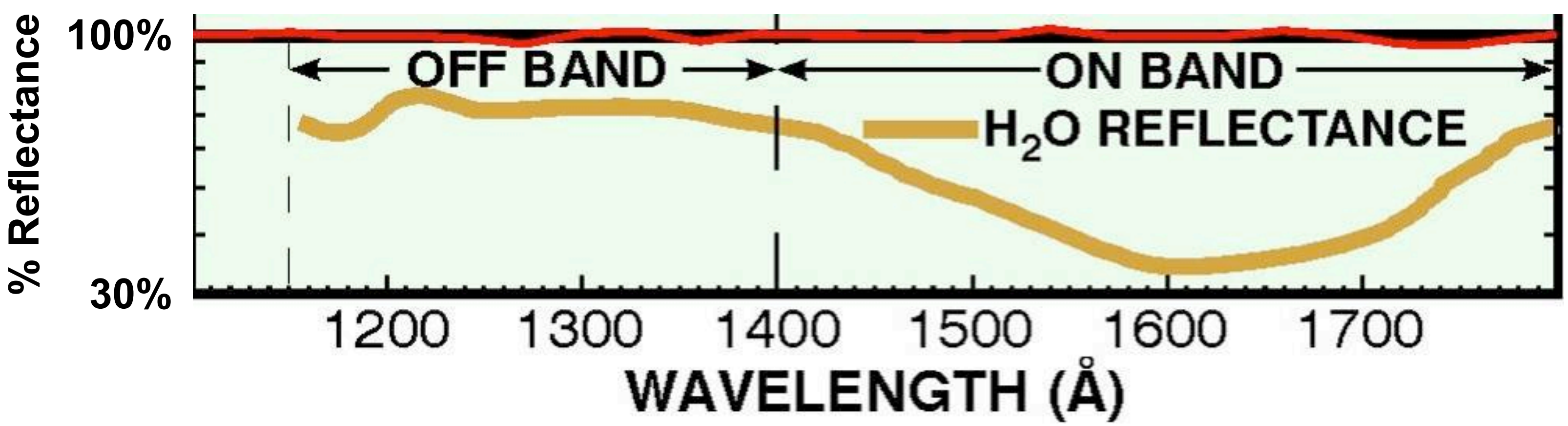
0.2º×6.0º slit

520-1800 Å passband

20 Å point source spectral resolution

LAMP Science/Measurement Summary

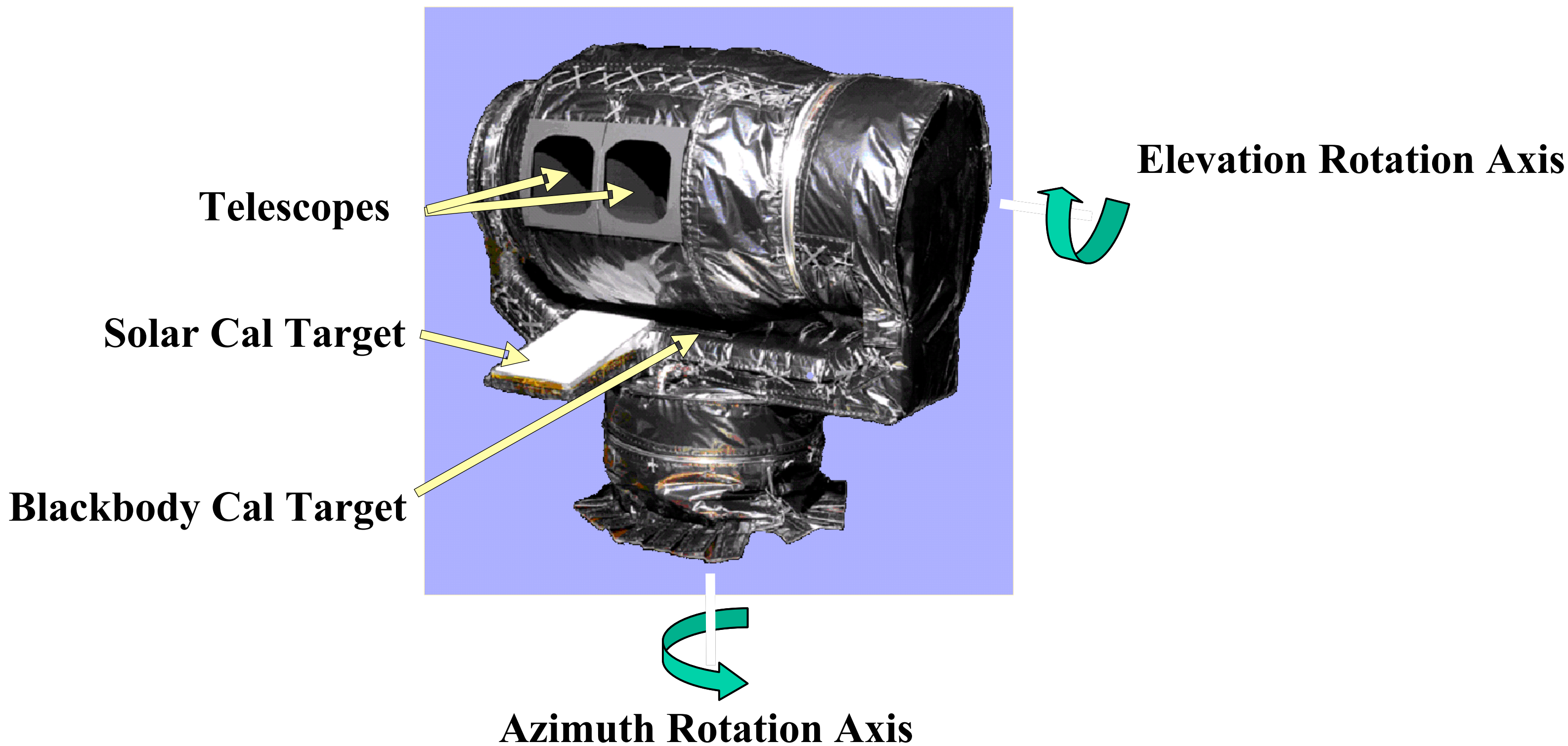
- LAMP will be used to identify and localize exposed water frost in PSRs
- LAMP will provide landform mapping (using Lyα albedos) in and around the permanently shadowed regions (PSRs) of the lunar surface.
- LAMP will demonstrate the feasibility of using starlight and UV sky-glow for future night time and PSR surface mission applications.
- LAMP will Assay the Lunar Atmosphere and Its Variability



Diviner Lunar Radiometer (DLRE)

David Paige PI, UCLA

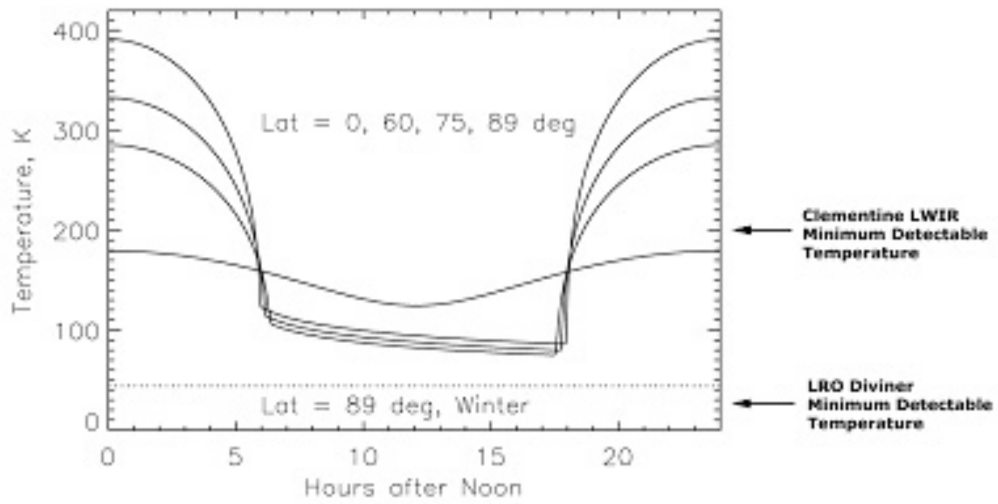
- Close copy of JPL's Mars Climate Sounder (MCS) Instrument on MRO
- 9-channel infrared radiometer 40K – 400K temperature range
- 21 pixel continuous pushbroom mapping with ~300 m spatial resolution and 3.15 km swath width at 50 km altitude
- Azimuth and elevation pointing for off-nadir observations and calibration



Diviner Investigation Goals

1. Characterize the moon's surface thermal environment
   - Daytime
   - Nighttime
   - Polar
2. Map surface properties
   - Bulk thermal properties (from surface temperature variations)
   - Rock abundance and roughness (from fractional coverage of warm and cold material)
   - Silicate mineralogy (8 micron thermal emission feature)
3. Characterize polar cold traps
   - Map cold-trap locations
   - Determine cold-trap depths
   - Assess lunar water ice resources (using Diviner data in conjunction with topographic data and models)

Clementine LWIR Daytime Thermal Image (200m /pixel)



Lunar day, night and polar temperatures

Cosmic Ray Telescope for the Effects of Radiation (CRaTER)

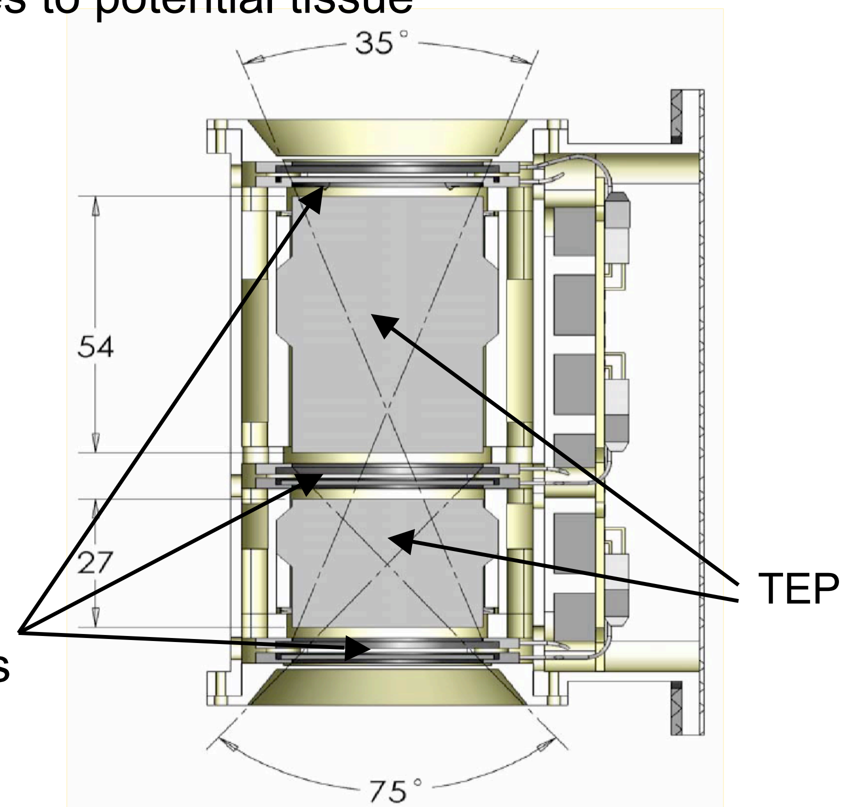
Harlan Spence PI, Boston University

CRaTER will measure the Linear Energy Transfer (LET) spectra behind tissue equivalent plastic (TEP)

LET spectra is the missing link connecting Galactic Cosmic Rays and Solar Energetic Particles to potential tissue damage

Characteristics

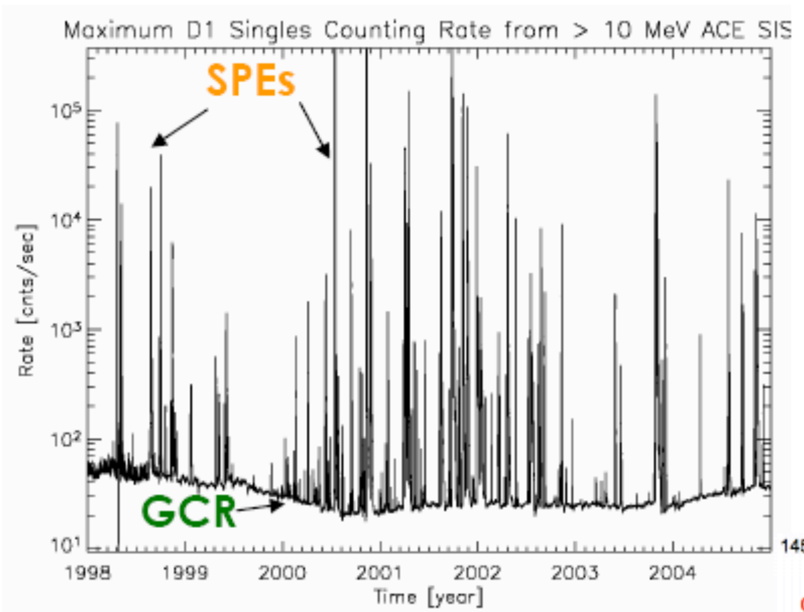
- Nadir FOV: 75°, Zenith FOV: 35°
- Avg. Orbital Power Allocation: 9.0 W
- Mass Allocation: 6.36 kg
- Daily Data Volume: 7.8 Gbits (Flare)
- Data Collection: Full Orbit (113 minutes)
- Inst. Daily Operations: Autonomous



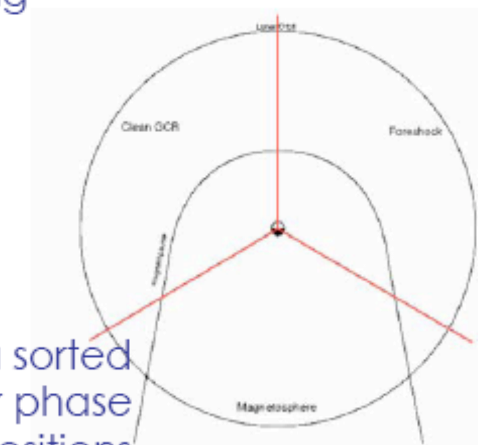
CRaTER Telescope

CRaTER Primary Science Overview

- LET spectra constructed for GCR/SPE independently, zenith & *nadir*
- Sorted according to lunar phase, LRO orbit phase, and lunar location
- *Will explore GCR fluctuations on **short** time scales (minutes to hours, of interest to LISA mission)*

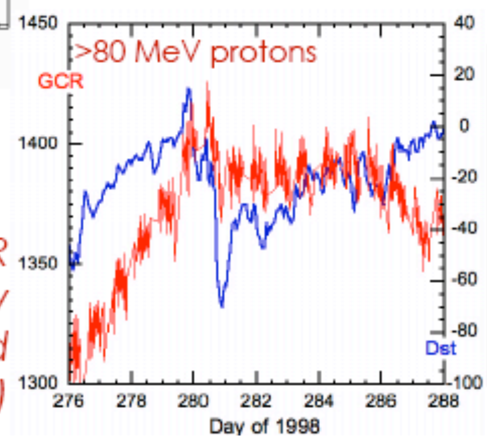


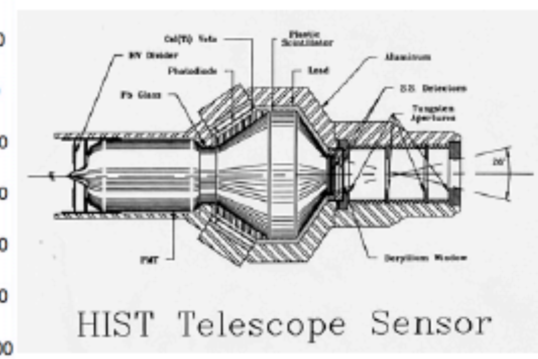
Predicted CRaTER counting rates based on historic GCR (low level, slowly varying) and SPE (intense, rapidly varying) observations



LET spectra sorted according to lunar phase and orbital positions

CRaTER will explore rapid GCR variations, discovered recently by NASA/Polar HIST (results presented at LISA meeting in UK)



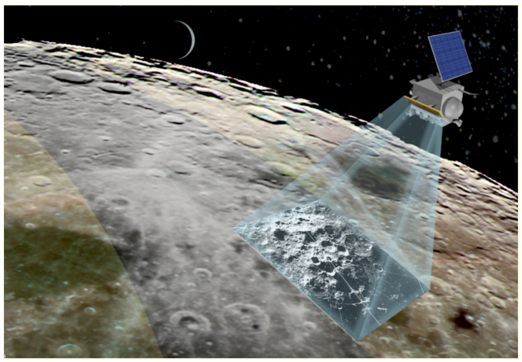


Miniature Radio Frequency Demonstration Project (Mini-RF)

Stewart Nozette PI,

Mini-RF Lunar Demonstrations

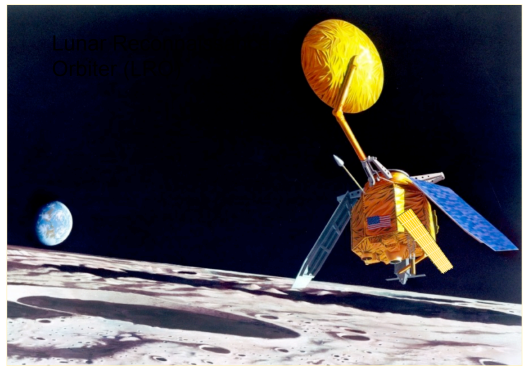
SAR Imaging (Monostatic and Bistatic)



Monostatic imaging in S-band to locate and resolve ice deposits on the Moon.

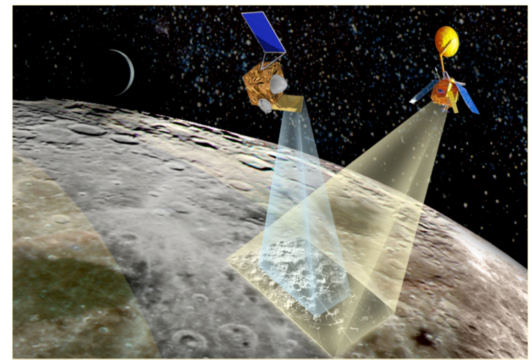
Communications Demonstrations

Component Qualification



Monostatic imaging in S-band and X-band to validate ice deposits discoveries on the Moon

X-Band Comm Demo

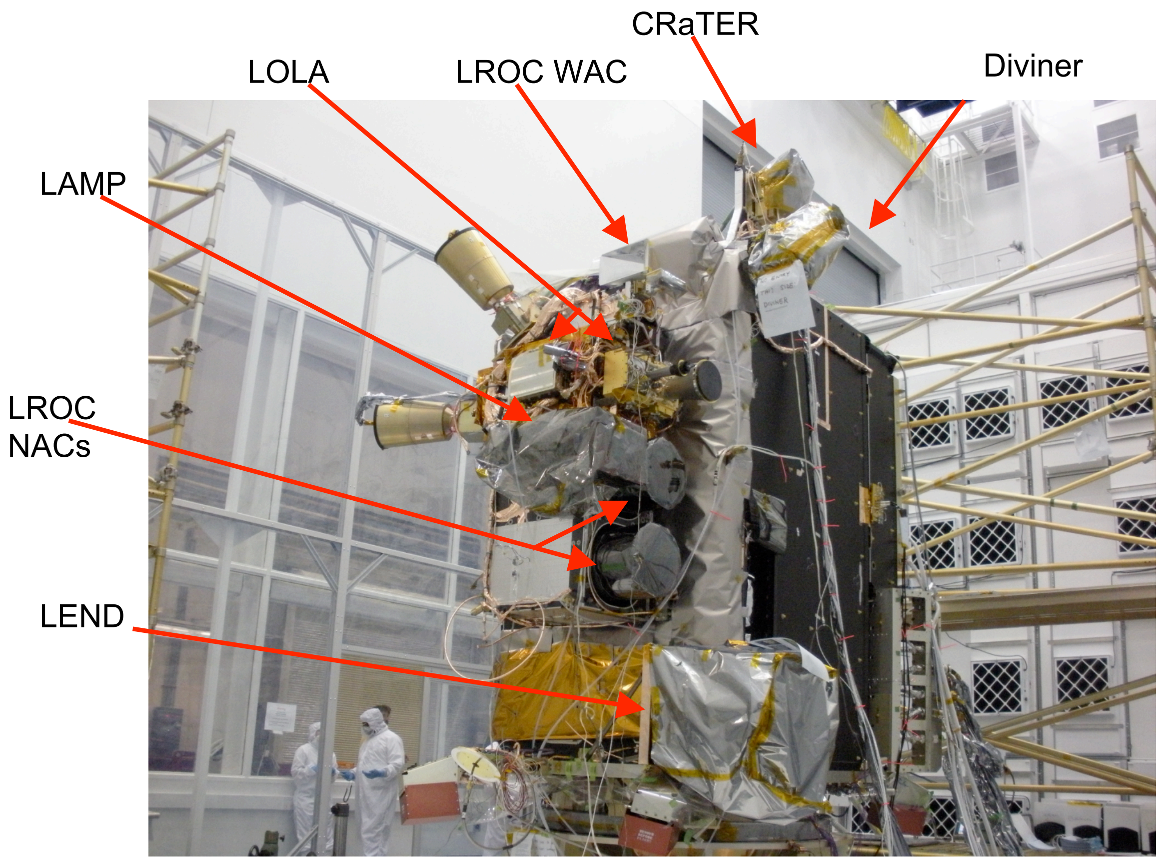


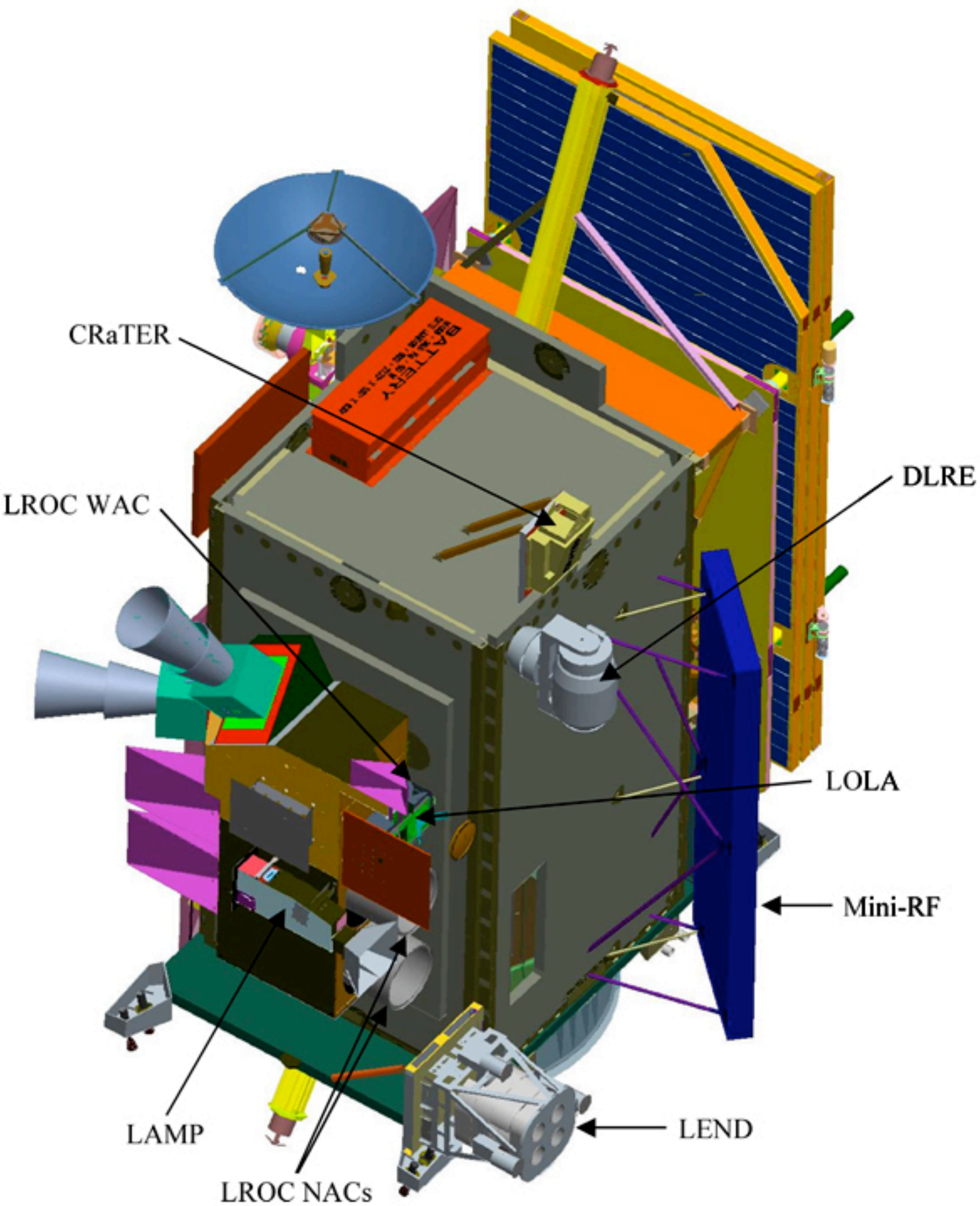
Coordinated, bistatic imaging in S-band, to be compatible with the Chandrayaan-1 and LRO spacecraft, can unambiguously resolve ice deposits on the Moon

Other Coordinated Tech Demos: e.g ranging, rendezvous, gravity

Current Status

- All Instruments Mounted on the Spacecraft
- All Subsystems installed
- First Comprehensive Performance test completed last week
- Pre-environmental Review taking place now leading to Vib. Acoustics and TV tests




CRaTER
LROC WAC
DLRE
LOLA
Mini-RF
LAMP
LEND
LROC NACs

Backups

LRO has robust and resilient capabilities

	Objectives	LRO Requirements	Contributing Instruments
1	Find Safe Landing Sites	M30 M40 – Global geodetic grid 10 cm vertical, and at the poles, 50 m horizontal resolution	LOLA, LROC
		M80 – Identify surface features & hazards	LROC, LOLA, DLRE
2	Locate Potential Resources	M50 – Provide lunar temperature map from 40 - 300K, 5 K precision over full diurnal cycle.	DLRE
		M60 – Image the permanently shadowed regions.	LAMP, LOLA
		M70 - Identify putative deposits of water-ice	LAMP,LEND, LOLA
		M90 – Characterize the polar region illumination environment	LROC, LOLA, DLRE
		M100 - Characterize lunar mineralogy	LROC, DLRE
		M110 - Hydrogen mapping	LEND
3	Life in the Space Environment	M10 - Characterize the deep space radiation environment at energies in excess of 10 MeV	CRaTER, LEND
		M20 - measure the deposition of deep space radiation on human equivalent tissue.	CRaTER
4	New Technology	P160 - Technology demo	Mini-RF